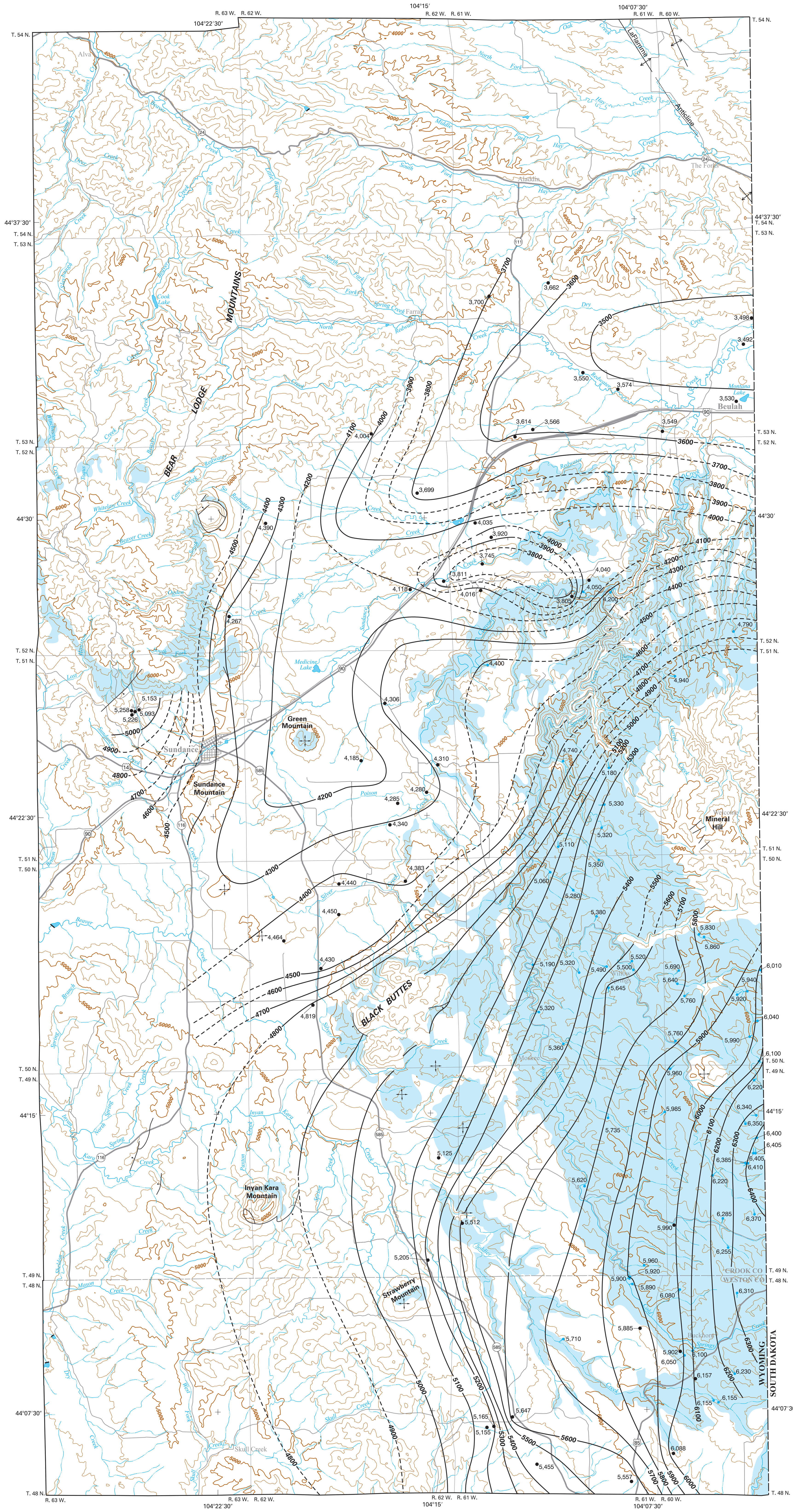
PREPARED IN COOPERATION WITH THE
WYOMING STATE ENGINEER'S OFFICE

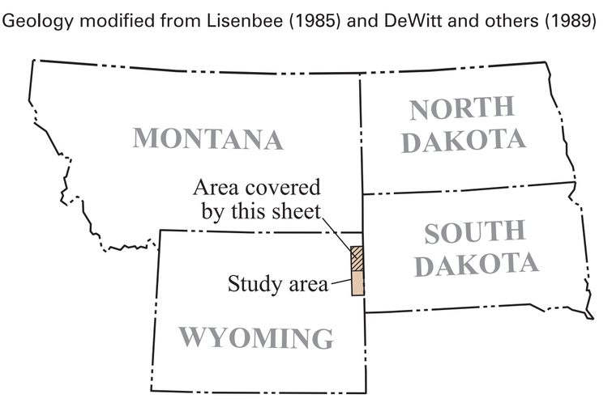


Planimetric base modified from U.S. Geological Survey digital data, 1:100,000: Devil's Tower, 1979; Lance Creek, 1981; Newcastle, 1979; and Sundance, 1979
Universal Transverse Mercator projection, Zone 13
North American Horizontal Datum 1927
Surface elevation contours derived from U.S. National Elevation Database (NED), 1999

Geology modified from Lisenbee (1985) and DeWitt and others (1989)

Potentiometric Surface of the Minnelusa Aquifer (northern part of the study area)

SCALE 1:100,000
0 1 2 3 4 5 6 7 8 9 10 MILES
0 1 2 3 4 5 6 7 8 9 10 KILOMETERS
LAND SURFACE CONTOUR INTERVAL 200 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988



EXPLANATION

- Outcrop of Minnelusa Formation (Lower Permian and Pennsylvanian)
- Outcrop of Madison (Pahasapa) Limestone (Lower Mississippian) and Englewood Formation (Lower Mississippian and Upper Devonian)
- 3600 — **Generalized potentiometric contour**—Shows approximate altitude at which water level would have stood in tightly cased wells completed in the Minnelusa or Madison aquifers, in feet. Contour interval 100 feet. Dashed where inferred or approximated. Datum is sea level[1]
- **Fault**—Dashed where concealed. Bar and ball on downthrown side
- **Anticline**—Showing trace of axial plane and direction of plunge. Dashed where concealed
- **Dome**—Symbol size approximately proportional to size of dome. Dome asymmetry indicated by arrow length
- 3,498 **Well**—Number is altitude of the water level measured in well, in feet above sea level[1]
- 4,200 **Spring originating from Minnelusa or Madison aquifer**—Number is altitude of spring, in feet above sea level[1]

[1]Sea level: In this report, the term "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)

INTRODUCTION

The topographically defined Black Hills and adjacent areas (Black Hills area) of Wyoming (fig. 1) are underlain by two regionally important aquifers—the Minnelusa and the Madison. The Minnelusa aquifer is used extensively in the Black Hills area as a source of domestic and livestock water. The Madison aquifer is an important source of municipal, industrial, agricultural, and domestic water in both the Black Hills area and other parts of Wyoming. Increased demand for water from the Minnelusa and Madison aquifers in the Black Hills area of Wyoming and South Dakota have created a need for better understanding of the hydrology of these two important aquifers.

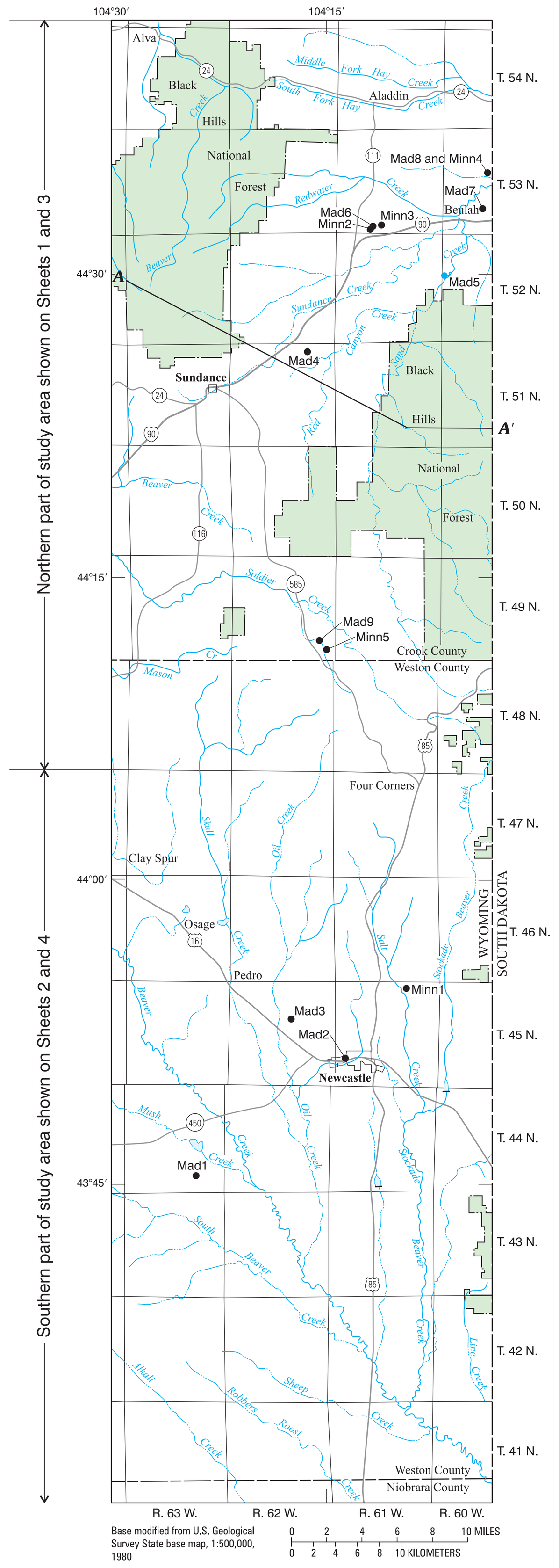


Figure 1. Location of the study area, line of geologic cross section, and selected wells and springs discussed in text, illustrations, and table 1 (sheet 2), Black Hills area, Wyoming.

This report presents information on the potentiometric surfaces and altitudes of the tops of the Minnelusa and Madison aquifers in the Black Hills area of northeastern Wyoming using new data collected since completion of earlier studies. In addition, ground-water levels in selected wells are examined, and the relative age of a limited number of ground-water samples are discussed. The information will be of use to government officials, land planners and other individuals who must manage the limited water resources of this growing and developing area.

The scope of the project was limited to wells and springs in the Black Hills area of Wyoming. Water levels were measured during 1998 and 1999 in wells completed in the Minnelusa and Madison aquifers to construct potentiometric-surface maps. The potentiometric surfaces and altitudes of the tops of the Minnelusa and Madison aquifers were contoured at the same scale (1:100,000) as studies of the aquifers recently conducted by the U.S. Geological Survey (USGS) in the Black Hills area within South Dakota (Carter and Redden, 1999a, 1999b; Strobel and others, 2000a, 2000b). The contours in these studies of the Minnelusa and Madison aquifers in South Dakota were "edge matched" as closely as possible along the Wyoming-South Dakota State line using the same contour interval. Use of the same contour interval and edge matching will allow for the use of the maps across State boundaries and improve understanding of the aquifers in a larger area within the Black Hills uplift. In places, some contours could not be matched across the Wyoming-South Dakota State line because this investigation was completed after the South Dakota investigations, and additional control points used in this investigation were located in Wyoming near the State line. The reader should note that Minnelusa and Madison outcrop areas and some structural features may not match in some areas along the Wyoming-South Dakota State line when maps in this study area are aligned or "edge matched" with maps produced for the South Dakota studies because different sources of geological mapping were used for the studies. Ground-water samples were collected from a subset of measured wells and analyzed for tritium to qualitatively estimate the time of ground-water recharge.

This project was conducted by the USGS in cooperation with the Wyoming State Engineer's Office (WSEO). The study area was almost entirely within Crook and Weston Counties in Wyoming and was bordered on the east by the Wyoming-South Dakota State line.

Previous Investigations

Investigations of the geology or hydrogeology of the Minnelusa and Madison aquifers in the Black Hills area have been conducted for about a century. The earliest known investigations are: Newton and Jenney, 1880; Darton, 1904, 1905, 1909; and Darton and O'Harra, 1905, 1907. The hydrogeologic investigations typically were conducted at two different scales—local and regional; the different scale of investigation often resulted in different interpretations of the characteristics of the Minnelusa and Madison aquifers by different investigators. Local investigations typically were conducted within an individual State's political boundary or within a specific geographic area (e.g., Black Hills area in Wyoming and South Dakota), while regional investigations typically were conducted in several States and interpreted the characteristics of the Minnelusa and Madison aquifers in relation to large regional aquifer systems comprising many aquifers. Many local and regional investigations describe the Minnelusa and Madison aquifers not only in the Black Hills area, but also in the adjacent Powder River Basin.

The name Powder River Basin commonly is used to identify both the drainage basin and the structural basin. In this report, all use of Powder River Basin will refer to the structural basin.

Most hydrogeologic investigations that include the Black Hills area in Wyoming emphasized the Madison aquifer, with comparatively little study of the Minnelusa aquifer. In some of these investigations, the Madison aquifer in the Powder River Basin and Black Hills area is defined as comprising not only rocks of the Madison Limestone, but also rocks suspected by the investigators to be in hydraulic connection with the Madison Limestone (Crist and Lowry, 1972; Swenson, 1974; Huntoon, 1976; Swenson and others, 1976). Earlier (prior to this investigation) potentiometric maps showing the direction of ground-water flow in the Madison aquifer or Madison aquifer and equivalent rocks in the Powder River Basin and Black Hills area within Wyoming and parts of surrounding States (i.e., surrounding parts of Montana and/or South Dakota) are presented in reports by Swenson (1974), Wyoming State Engineer's Office (1974), Swenson and others (1976), and Kyllonen and Peter (1987). Physical and hydraulic characteristics of the Minnelusa and Madison aquifers in the Black Hills area of Wyoming are discussed in Whitcomb and Morris (1964), Hodson and others (1973), Hodson (1974), Swenson (1974), Wyoming State Engineer's Office (1974, 1976), Blankennagel and others (1977), Kelly and others (1981), Feathers and others (1981), and Lowry and others (1986). Fitzwater (1981) examined the hydrogeology and geochemistry of the Minnelusa and Madison aquifers in northeastern Wyoming, including parts of the study area. The relationship between streamflow gains and losses and interaction with the Minnelusa and/or Madison aquifers in the Powder River Basin and Black Hills area in Wyoming was studied at selected streamflow-measurement sites in reports by the Wyoming State Engineer's Office (1974, 1976), Boner and others (1976), and Glass and Sultz (1992).

In contrast, both the Minnelusa and Madison aquifers were included in many local investigations of the aquifers in the Black Hills area of South Dakota. Many of these investigations were conducted by the USGS as part of a long-term study begun in 1990 in cooperation with the South Dakota Department of Environment and Natural Resources and the West Dakota Water Development District, which represents many local and county cooperators (Driscoll, 1992). The Minnelusa and Madison aquifers examined in these investigations are the same or very similar to aquifers present in Wyoming, and the aquifers usually are in direct hydraulic connection across the Wyoming-South Dakota State line; therefore, these investigations are important to understanding the characteristics of the Minnelusa and Madison aquifers in Wyoming. The reader is referred to Greene (1993), Greene and Rahn (1995), Hortness and Driscoll (1998), Greene and others (1999), Anderson and others (1999), Carter and Redden (1999a; 1999b), Strobel and others (1999), Strobel and others (2000a; 2000b), Carter and others (2001a; 2001b), and Driscoll and Carter (2001) for relevant local investigations of the hydrology of the Minnelusa and Madison aquifers in the Black Hills area of South Dakota. Kyllonen and Peter (1987) studied the hydrology of the Minnelusa and Madison aquifers in the Black Hills area of both Wyoming and South Dakota, including parts of the study area. The geochemistry of the Minnelusa and Madison aquifers in the Black Hills area of South Dakota was recently described in Naus and others (2001). Selected results from many of these studies are briefly discussed herein.

Many regional investigations of the Minnelusa and Madison aquifers were conducted by the USGS as part of the Madison Limestone study begun in 1975 (U.S. Geological Survey, 1975) and the Northern Great Plains Regional Aquifer-System Analysis (RASA) study started in the late 1970's (U.S. Geological Survey, 1979). In addition to collection of new data, these regional investigations also used information from many of the local-scale investigations previously discussed. The reader should note that the investigators commonly defined the Minnelusa and Madison aquifers as part of an aquifer system comprising not only the Minnelusa Formation and Madison Limestone, but also other formations believed to be equivalent to or in hydraulic connection with the formations in Wyoming, Montana, North Dakota, and South Dakota. Potentiometric maps constructed during these studies are regional in scope and show the direction of ground-water flow in the Minnelusa and Madison aquifers and equivalent rocks in the Powder River Basin and Black Hills area within Wyoming, Montana, North Dakota, and South Dakota (Miller and Strausz, 1980; Downey, 1984; Downey and Dinwiddie, 1988). Physical and hydraulic characteristics of the Minnelusa and Madison aquifers and associated rocks were described in Sando (1976a, 1976b), Peterson (1978, 1984), MacCary and others (1983), Thayer (1983), Brown and others (1984), Downey (1984, 1986), MacCary (1984), Lobmeyer (1985), Cooley and others (1986), and Downey and Dinwiddie (1988). In addition, the geochemistry of the Madison aquifer is discussed in Hanshaw and others (1978), Plummer and Back (1980), Back and others (1983), Busby and others (1983), Plummer and others (1990), Busby and others (1991), and Busby and others (1995).

Geology

The Black Hills uplift is an asymmetric dome (anticlinal upwarp) in Wyoming, South Dakota, and Montana that was formed about 60 to 65 million years ago during the Laramide orogeny. The uplift trends north-northwest, is about 175 miles long and 90 miles wide, and is bounded by monoclines on the west and east (DeWitt and others, 1986). Erosion has exposed outcrops of shallow marine to nearshore-terrestrial Paleozoic and Mesozoic sedimentary rocks (commonly as hogback ridges) that encircle Precambrian igneous and metamorphic rocks that form the core (fig. 2) of the Black Hills. The sedimentary rocks dip away from the igneous and metamorphic core and are locally interrupted by monoclines, folds, faults, and Tertiary igneous intrusions. The slopes of the dome structure of the uplift are gentler on the western side (Wyoming) than on the eastern side (South Dakota). Two blocks comprise the Black Hills uplift: a western, structurally lower block bounded on the west by the Black Hills monocline and bounded on the east by the Fanny Peak monocline, and an eastern, structurally higher block bounded on the east by a homoclinal dip slope and bounded on the west by the Fanny Peak monocline (Lisenbee, 1978, 1985). The Fanny Peak monocline separates the two blocks. The Black Hills and Fanny Peak monoclines are shown on the maps on sheets 2 and 4.

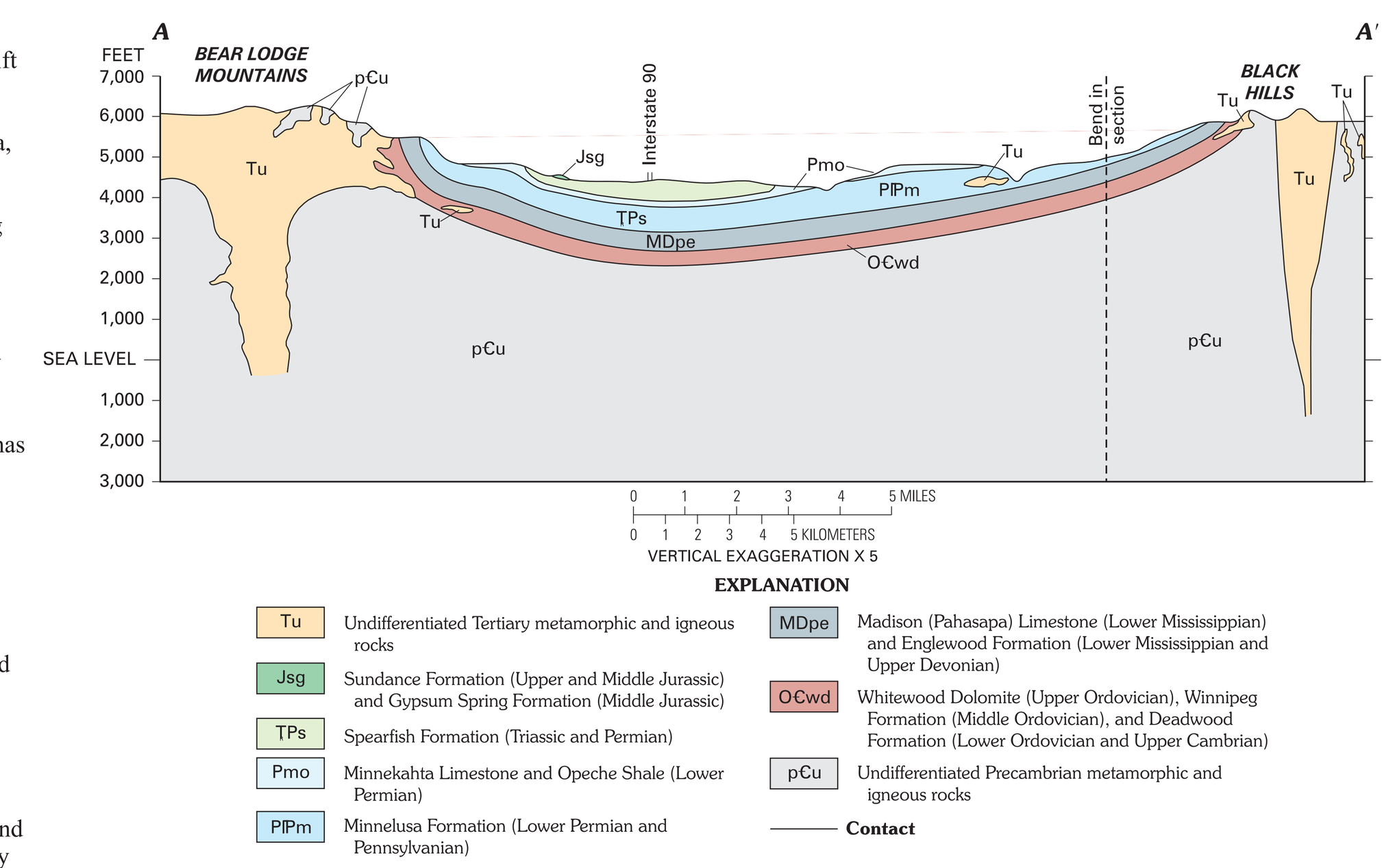


Figure 2. Geologic cross section. Line of geologic cross section shown in figure 1. Modified from DeWitt and others (1989).

Acknowledgments

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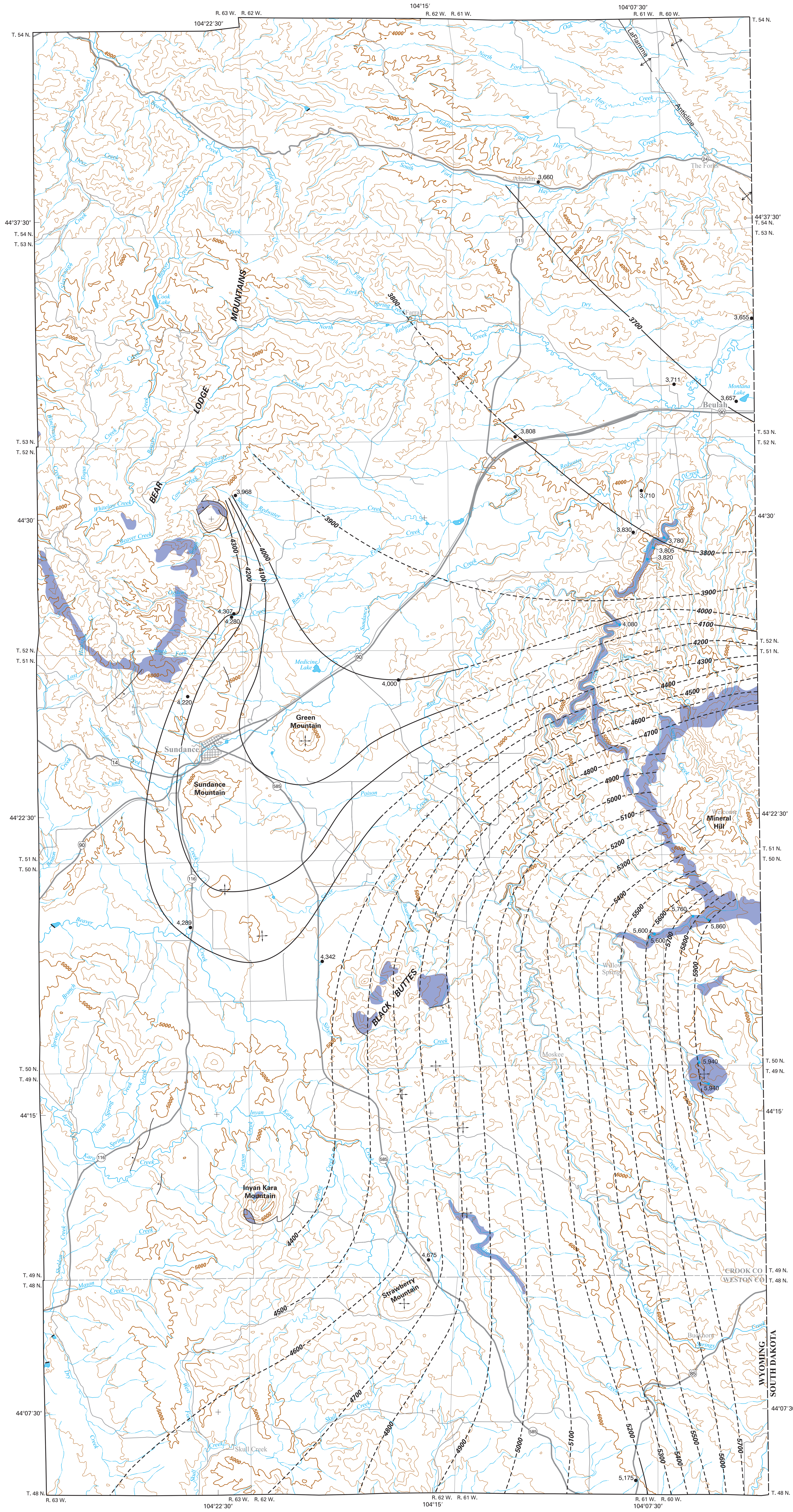

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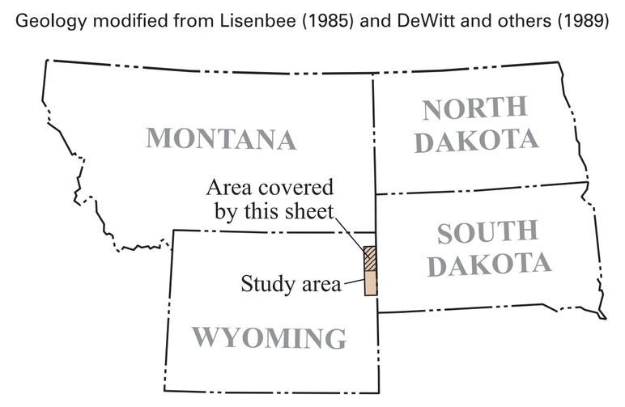

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Potentiometric Surfaces, Altitudes of the Tops, and Hydrogeology of the Minnelusa and Madison Aquifers, Black Hills Area, Wyoming

by
Timothy T. Bartos, Laura L. Hallberg, and Kathy Muller Ogle
2002